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Local vs. Global Environmental Degradation: Investigating the Environmental Kuznets Curve in Egypt

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*Local Versus Global Environmental Degradation: Investigating the Environmental Kuznets Curve in Egypt**

Mohamed Nabil Elimam

Abstract

The environment versus development debate is a long and fierce one with important policy implications. A significant portion of the vast literature written on the topic is dedicated to the investigation of the Environmental Kuznets Curve (EKC) hypothesis that proposes an inverted U – shaped relationship between environmental degradation and economic development. While this relationship was discussed extensively on panel data from different groups of countries, limited empirical work has been published on time series data, and even less on Egypt. This study aims to investigate the relationship between CO_2 emissions per capita, SO_2 quantities in air and the GDP per capita by estimating two separate models employing the Autoregressive Distributed Lag (ARDL) technique. To improve the accuracy of the model, several other explanatory variables are accounted for, namely energy use per capita, alternative energy use per capita and the value added from agricultural, industrial and services sector to the GDP. The results refute the existence of the EKC relationship for both CO_2 and SO_2 on the long and short runs.

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*This paper was written as part of the Quantitative Methods course. Any questions or queries related to this working paper may be sent directly to m.nabil@aucegypt.edu.

Introduction:

As a coastal nation characterized with low lying shores, Egypt is considered highly vulnerable to sea level rising and other damaging effects caused by climate change (Frihy and El-Sayed, 2012; Smith et al., 2013). Such concerns, shared by the global audience, have led to several initiatives for countries to work together to limit the effects of global warming and climate change, most notably the Kyoto Protocol and Paris Agreement which specify targets for limiting emissions that contribute to the global climate change phenomenon (Streck, Keenlyside and Unger, 2016). Nevertheless, application of such agreements have proven to fall short of targets, with global emissions actually increasing (Rosen, 2015).

Focusing on Egypt, data published by the World Bank (2014) show that annual CO_2 emissions have had a general rising trend with several minor reduction periods in years with global or local economic slowdown. Hence, researchers discussed extensively the impacts of climate change on various economic activities in the country. Alboghdady and El-Hendawy (2016) showed that a 1% increase in temperature in winter caused a 1.12% drop in agricultural production. Moreover, environmental degradation has been empirically shown to have adverse effects on tourism (Sghaier et al., 2018), water resources quality and supplies (Yehia et al., 2017), and human health resulting from increased use of pesticides (Delcour et al., 2015). This is why, many tribal societies place cultural importance on the conservation of the environment (Shafik, 1994).

To combat the aforementioned adverse effects, the Egyptian Government applied several projects with the purpose of reducing environmental degradation with varying results. Earlier programs including transformation of vehicles to run on natural gas that started in 1992 have been showing a consistent accelerating upwards trend (Badran, 2004). Other more recent projects like those combating rice straw burning and conversion of light bulbs to energy – saving modules have also shown promising results, resulting in the designation of Egypt as a green economy flagship country by the UN Environment Programme.

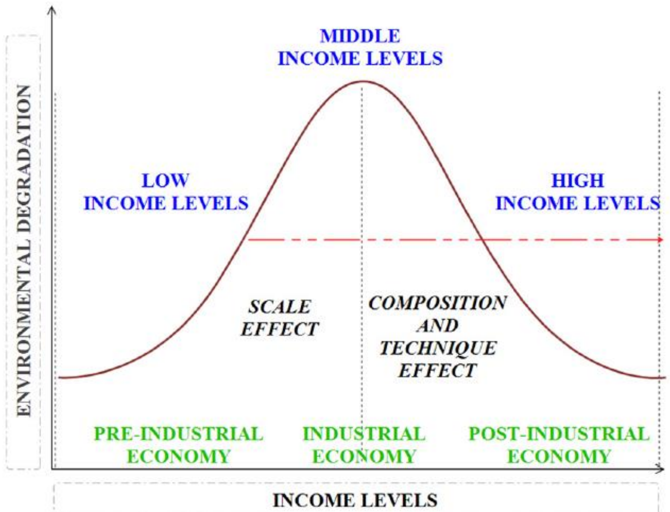
From a more technical perspective, Herndon (2018) showed that particulates in air, caused by human influences (Karl and Trenberth, 2003), are the main causes of climate change. Hence, measurements of pollutants in air like CO_2, SO_2, NO_x and SPM are typically used as indicators for environmental degradation (Selden and Song, 1994; Stern et al., 1996). This paper, motivated by the severity of pollution impacts, studies the empirical relationship between economic growth and environmental degradation. In doing so, it tests the validity of the Environmental Kuznets Curve (EKC) hypothesis in the Egyptian case. Beyond this introduction, the paper is structured as follows: a literature review of published works on economic development versus environment dilemma and different models describing it, a contextual framework for the empirical study to be done, a description of the data sets used for the analysis along with some descriptive statistics and graphs, statement of the econometric model applied, main empirical findings and their discussion, and finally policy implications and recommendations resulting from the study and a conclusion summing up the work done.

Literature Review:

To properly investigate the effect of economic development on environmental quality, it is first important to survey the literature written on the subject. The growth versus environment debate has long been a topic of research. The pessimistic side of the debate adopted by (Cleveland et al., 1984) and other physical scientists argue that economic development necessarily means larger consumption of natural resources and energy leading to environmental degradation and overwhelming the ecosystem. Jansson et al. (1994) even predicted that this environmental degradation will eventually cause economic collapse. Hence, the only way to stop environmental degradation would be to slow down economic growth and opt for a steady, stable economy. On the other optimistic side of the debate, there exists literature including (Beckerman, 1992) that argue that economic development is the fastest way for environmental recovery.

The aforementioned understandings were further developed into several theoretical models, summarized by Panayoutou (2000). The main categories of models include: (A) Optimal growth models (Selden and Song, 1995; Tahvonen and Kuuluvainen, 1993) and others look into the trade – off between pollution and the utility of consumption. (B) Models of the environment as a factor of production (Lopez, 1994; Bovenberg and Smulders, 1995; Bovenberg and Smulders, 1996) consider the environment a stock of natural capital the economy is endowed with. In other words, the environment itself generates output. In such models, environmental regulations alone will not maintain environmental quality.

Nevertheless, many researchers support a third viewpoint on this relationship in which the function is not constant along the path of economic development. Empirical results found by Grossman and Krueger (1991) who studied the effects of the North American Free Trade Agreement (NAFTA) on environmental quality in Mexico, showed an inverted U – shaped relationship between environmental degradation and economic development. Subsequent empirical work also gave similar results which led to Panayoutou (1993) naming this phenomenon the Environmental Kuznets Curve (EKC) by analogy to the work developed by Kuznets (1955) who found an inverted U – shaped relationship between income inequality and economic development. The main principle is that in a given country at lower income levels, i.e. in the developing phase of the economy, most activities are heavily polluting and as such activities increase, environmental degradation worsens. However, at higher income levels, i.e. in the developed phase of the economy, activities become more technologically advanced and pollution levels start to drop. Figure (1) represents this relationship graphically.



This gave birth to a vast field of research in which numerous papers were written that can be grouped into sub – topics: (A) testing the validity of the EKC using different data sets and empirical techniques, (B) discussing theoretical frameworks explaining the phenomenon and (C) developing critiques for it. The following is a brief review of each sub – topic.

Testing validity of EKC hypothesis

Since the nineties, numerous empirical studies were conducted to test the validity of the EKC hypothesis on different data sets and methodologies. Sarkodie and Strezov (2019) performed an in – depth review of the empirical studies using meta – analysis and bibliometric analysis techniques. They concluded that most studies focused on atmospheric indicators as representatives for environmental degradation. Moreover, it was found that for studies that did prove the existence of an EKC, the average turning point for the curve is at an income level of US$ 8910. For the case of Egypt, limited literature is published in the topic. Ibrahiem (2016); Abdou and Atya (2013) and El-Aasar and Hanafy (2018) found no proof for the existence of an EKC relationship in Egypt. Meanwhile, Mahmood et al. (2019) used data for Egypt's post liberalization period (1990 – 2014) and confirmed an EKC relationship.

Discussing theoretical frameworks explaining the phenomenon

In his review of the literature, Bo (2011) mentioned the perception of EKC in which:

> "more economic activities mean more environmental pollution based on the assumption that technology, preference and environmental investment are constant", "but people will pay more attention to environment issues and resolve it with increasing income, consequently, environmental pollution level will decrease"

This understanding builds on the previous literature's explanation of why EKC arises. The simplest reason being the income elasticity of environmental degradation (Beckerman, 1992; Baldwin,

1995) where environmental quality is demanded more at higher levels of income. In addition, several underlying causes including environmental awareness and education lead to the consumers pivoting towards more environmentally responsible products (Stern, 2002). Another reason is the relationship between scale, structure and technology (Grossman and Krueger, 1991; 1995) where the scale effect is the increase in pollution resulting from consumption of energy and natural resources to produce more goods and services. Meanwhile, structure effect is the improving environmental situation resulting from changes in the structure of economic activity as the economy develops, and the technology effect is the reduced pollution resulting from more efficient production techniques. Other explanations include the effects of foreign trade and foreign investment. According to Antweiler et al. (2001) and Liddle (2001), free international trade results in a pollution haven in developing countries, where developed countries stop producing heavily polluting goods, thus improving their environmental conditions, and leave their production to developing ones. Adopting this explanation would mean that in the future, there will either be less pollution havens available (Stern, 2003) that become even more polluted as developed economies enforce stricter regulations (Tobey, 1990; Rock, 1996 and Harrison, 1996) or the EKC would become a historical artifact (Cole, 2004). Moreover, the environmental improvement seen would only be local and global degradation would not change (Nahman and Antrobus, 2005).

Critiques of EKC

Depending on the empirical results they get, researchers would come up with different critiques and policy implications. In the simplest format, the EKC relationship would mean that environmental problems can be solved through economic development. However, several concerns were raised in this regard. Grossman and Krueger (1994); Shafik (1994); Dinda et al. (2000); Özokcu and Özdemir (2017) and others found an N – shaped relationship rather than an inverted U – shaped one indicating that environmental degradation decrease might be temporary and would actually increase again at higher levels of income. This is why Grossman and Krueger (1995) argued that only strong pressure for environmental policies can reduce pollution and not just economic development. Furthermore, Harbaugh et al. (2002); Millimet et al. (2003); Dinda (2004) raise the concern that EKC may only be a statistical phenomenon arising from data manipulation, thus it bears no policy significance. On the other hand, believers in the EKC model conclude that international cooperation and transfer of knowledge and technology from developed to developing nations can help curb polluting emissions (Dasgupta et al., 2002).

Contextual Framework:

In order to be able to achieve the research objectives mentioned in the introduction, a clear theoretical framework must be identified. The empirical econometric model to be applied will be built upon this framework and discussed in a subsequent section of this paper. Previous literature reviewed earlier have used different variables to test for the validity of the EKC hypothesis. For example, the dependent variable referring to environmental degradation can be any of many indicators measured and reported regularly by governments, research centers and NGOs worldwide. Such variables include: water cleanliness, suspended particles in water, dissolved oxygen in water, fecal forms in river streams, deforestation rates, amounts of municipal waste per capita, CO_2, NO_x, SO_2, black smoke emissions and other variables (Shafik, 1994). As for the explanatory variables, most researchers agreed on using real GDP per capita as an indicator for economic growth. Nevertheless, there are a multitude of options when it comes to other independent variables added to the model to improve its accuracy, measured through R^2 value, and significance of each variable, measured through t – statistic. The literature reviews by Stern et al. (1996), Panayoutou (2000) and Sarkodie and Strezov (2019) offer excellent summaries of what variables were used in previous research.

In this paper, two separate models are used to test the validity of the EKC hypothesis. Both models share the same explanatory variables, discussed later on, with the difference being in the dependent variable referring to environmental degradation, where one model uses CO_2 emissions per capita and the other uses SO_2 amounts in air. As mentioned in the introduction above, air quality is an important indicator of the environmental conditions. Nevertheless, there are several air quality indicators being measured by various entities. The two selected indicators were chosen specifically because, according to Rothman (1998) and Stern (1998), CO_2 is more affected by global trends rather than local ones and it is quite difficult to be mitigated through efforts and policies of individual countries. Hence, most studies using CO_2 as an indicator for environmental degradation fail to prove the existence of an EKC. On the other hand, SO_2 is a locally generated pollutant that can easily be affected by local government policies making the EKC model more applicable.

As for the explanatory variables, they are the same for both models to make the comparison of results easier. The main variable in the relationship is the GDP per capita used as an indicator for economic growth. Picardo (2019) discussed the meaning and value of GDP per capita and why it is considered the best representative for the effect of economic growth on the population. As for the other explanatory variables included in both models, inspired by the work of Shahbaz et al. (2010) who identified the top five sectors responsible for 55% of all CO_2 emissions to be the extraction of oil, oil refining, electricity distribution, construction, land transport and transport via pipeline, the selection of the independent variables was made to take the above sectorial nature of the economy into account. More details on the variables used, their sources and units of measurement can be found in the next section.

Data Used:

To verify the EKC model in the Egyptian case as per the aforementioned framework, time series data sets were obtained from two main sources: (A) World Bank's World Development Indicators (WDI) published data sets for CO_2 emissions per capita, energy consumed per capita, percentage of alternative energy consumed of total, GDP per capita, percentage of value added from agricultural, industrial and services sectors in GDP, and (B) Egypt's Ministry of Environment annual state of the environment reports published from 1999 to 2016 for SO_2 quantities in air. Details on all the data sets can be found in table (1).

Table 1: Summary of data sets used

Variable	Description	Unit of measurement	Years of availability	Source
CO2_PerCap	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	metric tons per capita	1960 - 2018	World Bank WDI
SO2	Average annual value of SO2 emissions in air measured by Egyptian Ministry of Environment through 90 stations in different geographical locations.	microgram per cubic meter	1999 – 2016	Egypt MoEnv
GDPperCap	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars.	current USD per capita	1965 – 2018	World Bank WDI
EnergyUsePerCap	Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.	kg of oil equivalent per capita	1971 – 2014	World Bank WDI
AltEnergyUsePerCap	Clean energy is noncarbohydrate energy that does not produce carbon dioxide when generated. It includes hydropower and nuclear, geothermal, and solar power, among others.	kg of oil equivalent per capita	1971 – 2014	World Bank WDI

Agri	Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3 or 4.	Current USD	1960 – 2018	World Bank WDI
Indust	Industry corresponds to ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37). It comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3 or 4.	Current USD	1960 – 2018	World Bank WDI
Serv	Services correspond to ISIC divisions 50-99 and they include value added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services. Also included are imputed bank service charges, import duties, and any statistical discrepancies noted by national compilers as well as discrepancies arising from rescaling. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The industrial origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3 or 4.	Current USD	1960 – 2018	World Bank WDI

Before getting into regression analysis, some visual representations of data are generated to develop a better understanding of the data sets and come up with expectations of the results.

Figure (2) shows the time trends of CO_2 emissions per capita and SO_2 amounts in air over the years. It can be seen that while CO_2 is increasing overall with the increase of population and economic activity, the trend for SO_2 is dropping as a result of government policies undertaken after issuing the Egyptian environmental law (law number 4 of 1994) that imposed legal limits on air pollutant emissions from factories, vehicles and other activities. More details on the law and its amendments can be found through the American Chamber of Commerce in Egypt.

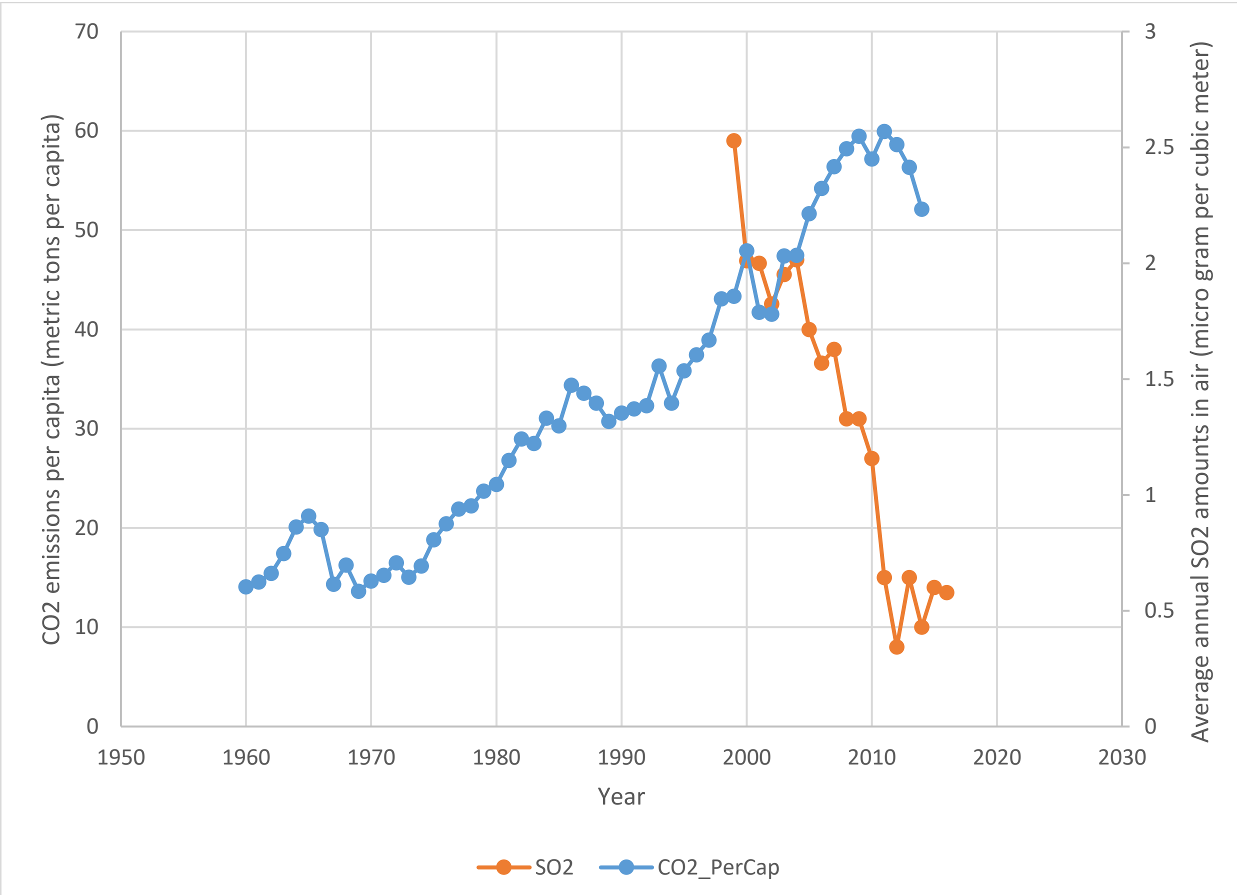


Figure 2: Time trends of CO2 emissions per capita and SO2 amounts in air over the years

Applying the same analysis to the time trends of energy use per capita and GDP per capita, figure (3) shows that both have almost identical time trends, with corresponding episodes of increasing and decreasing, with minor lag. This follows the common understanding that energy consumption is an indicator for economic growth and increases as the income levels of individuals increase (Wolde-Rufael, 2006).

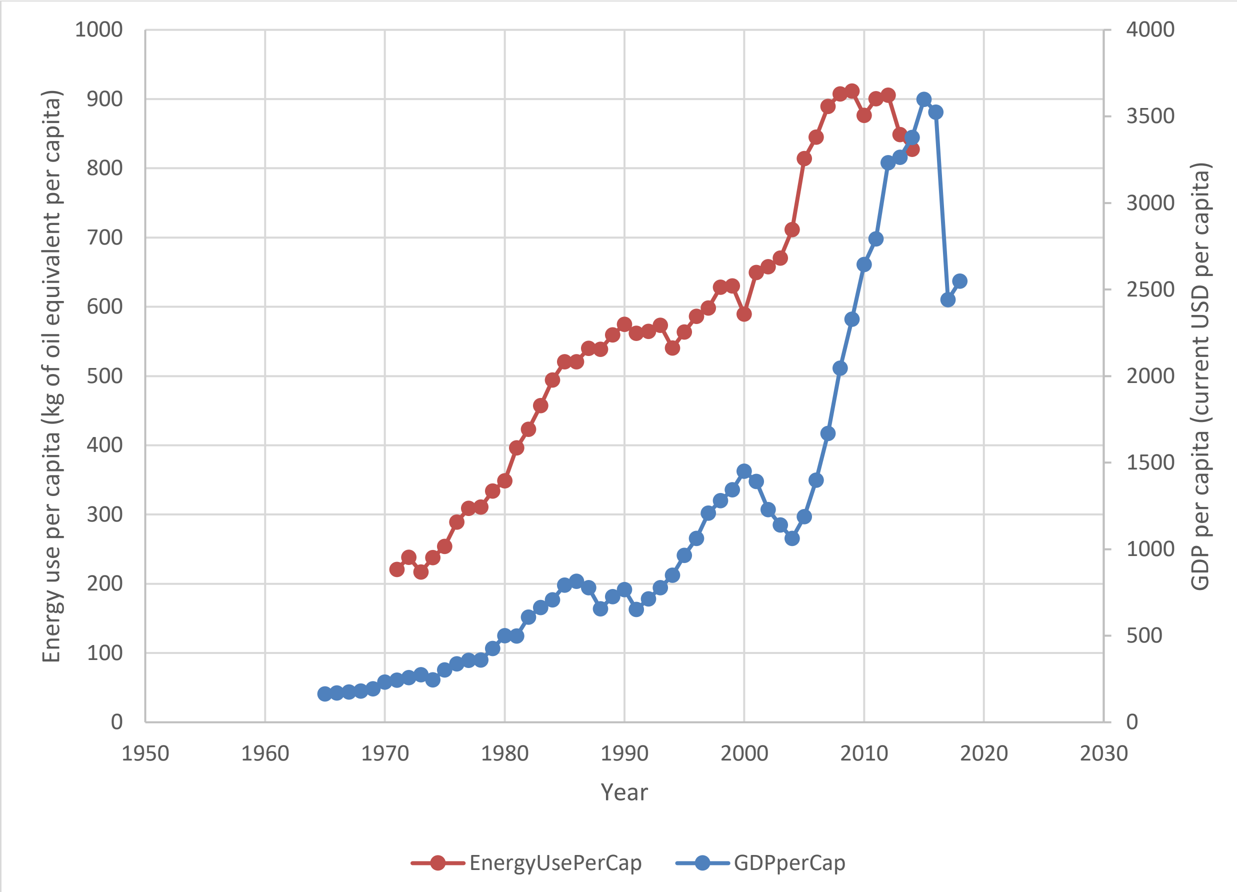


Figure 3: Time trends of energy use per capita and GDP per capita over the years

Looking at the trends of energy use, figure (4) shows the growth of energy use per capita in Egypt and how it relates to the use of alternative renewable resources. While the total energy consumed per person is rapidly increasing as discussed earlier, the amount of energy output from renewable resources is fairly constant over the period of available data (1971 – 2014) meaning that the percentage is dropping. Nevertheless, the Egyptian government has taken several steps to increase is generation capabilities from renewable resources with the introduction of new wind farms in Ras Ghareb region in 2017 and the huge solar power park in Benban currently under construction. Hence, if this same analysis is applied on later data, the situation yielded would likely be a better percentage of renewables to the overall energy use. More details can be found through the Renewable Energy Outlook: Egypt report published by IRENA (2018).

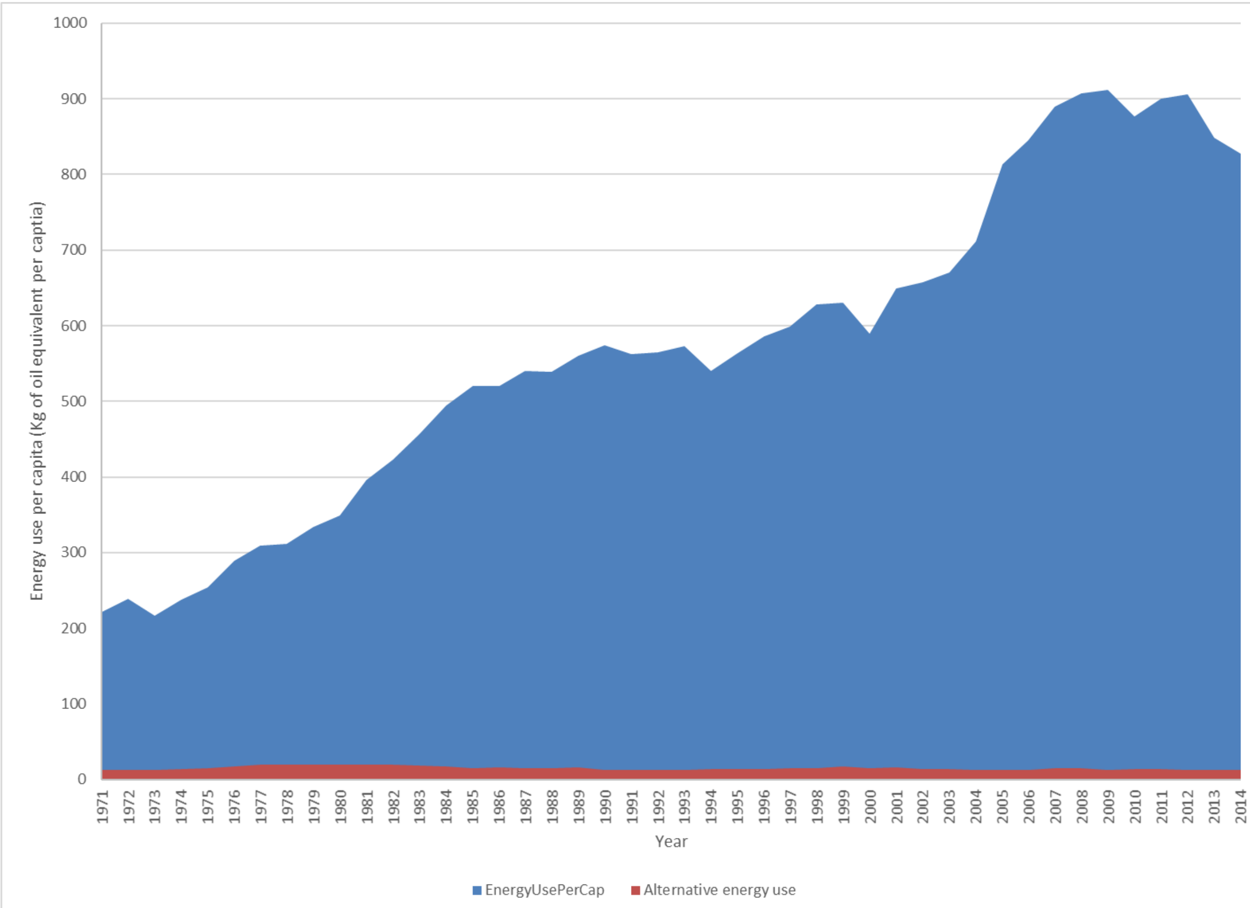


Figure 4: Growth of overall energy use per capita in Egypt compared to alternative energy use

Finally, looking into the shares of each sector in the GDP, figure (5) shows the distribution of GDP over the three sectors and how that changes over the years. It is clear that the agricultural sector is generally losing its position as the main sector of the economy in favor of the industrial and services sectors. Moreover, recent years have seen a revival in the role of industrial sector, driven by construction, as a result of the mega projects lead by the government in this field.

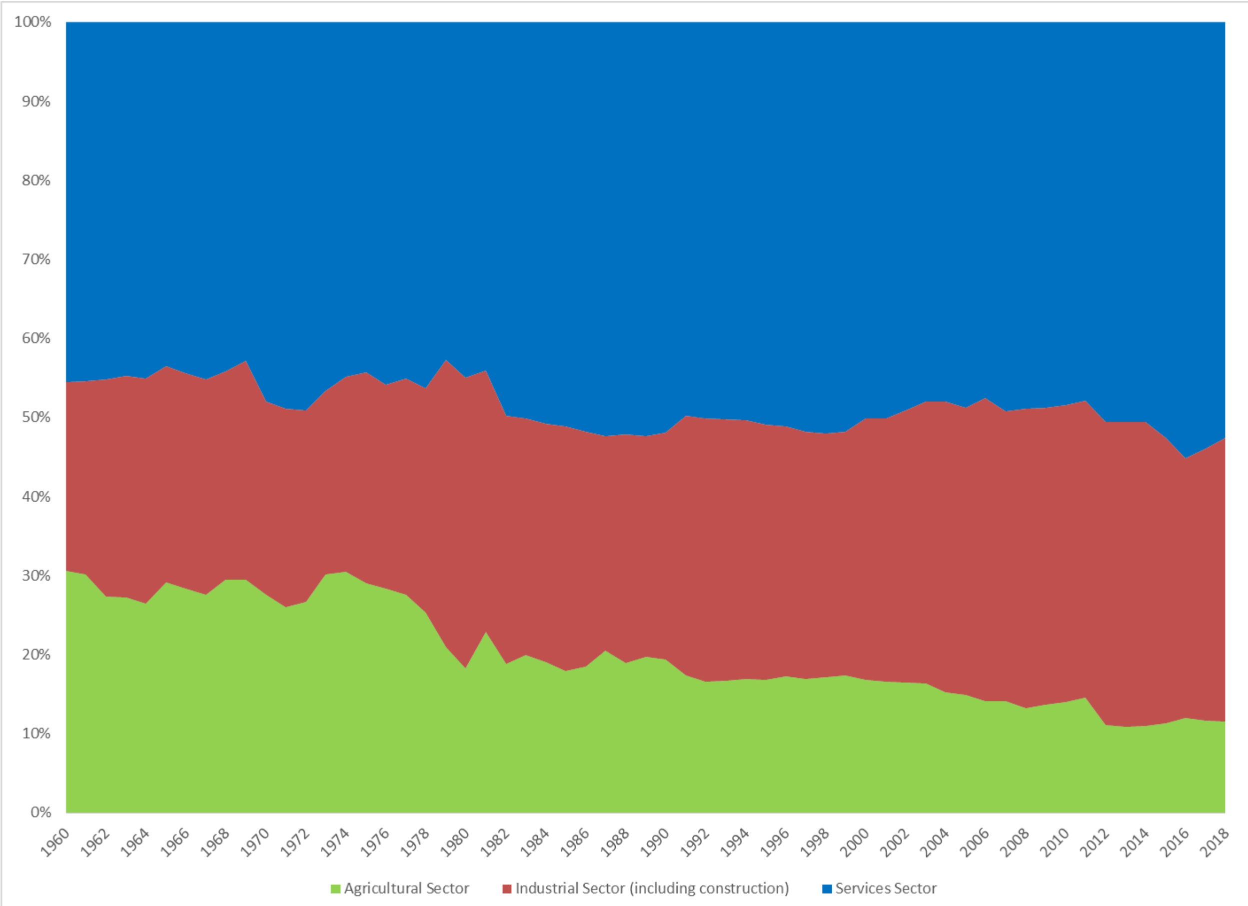


Figure 5: Shares of main economic sectors of the GDP

Moreover, it is also useful to report some descriptive statistics on the variables used in the regression models before starting the regression. Table (2) reports the main descriptive statistics for the variables used in the CO_2 regression model, and table (3) reports the same statistics for variables used in the SO_2 model.

Table 2: Descriptive statistics for variables of the CO2 model

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Ln (CO_2 emissions per capita)	55	0.237	0.472	-0.537	0.944
Ln (GDP per capita)	54	6.687	0.903	5.094	8.188
Ln (Energy use per capita)	44	6.264	0.424	5.380	6.815
Ln (Alternative energy use per capita)	44	1.019	0.501	0.317	1.832
Ln (Agriculture sector	54	22.77	0.984	20.97	24.39

value added to GDP)					
Ln (Industrial sector value added to GDP	54	23.31	1.399	20.90	25.53
Ln (Services sector value added to GDP	54	23.75	1.322	21.37	25.92

Table 3: Descriptive statistics for variables of the SO2 model

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Ln (SO_2 emissions per capita)	18	3.295	0.617	2.079	4.078
Ln (GDP per capita)	54	6.687	0.903	5.094	8.188
Ln (Energy use per capita)	54	45.51	12.03	25.95	67.05
Ln (Alternative energy use per capita)	44	6.264	0.424	5.380	6.815
Ln (Agriculture sector value added to GDP)	44	1.019	0.501	0.317	1.832
Ln (Industrial sector value added to GDP	54	22.77	0.984	20.97	24.39
Ln (Services sector value added to GDP	54	23.31	1.399	20.90	25.53
	54	23.75	1.322	21.37	25.92

Econometric Model:

As mentioned earlier, this study employs two separate regression models with the same independent variables and different dependent ones. For the sake of simplicity, the model with CO_2 emissions per capita as dependent variable will be denoted model (A) and the model with SO_2 in air as dependent variable will be denoted model (B). In light of the study objectives and data sets described earlier, the following equations were specified:

$$CO_{2_t} = f(GDP_t \,.\, GDPp_t^2 \,.\, Energy_t \,.\, AltEnergy_t \,.\, Agri_t \,.\, Indust_t \,.\, Serv_t) \quad (A1)$$

And

$$SO_{2_t} = f(GDP_t \,.\, GDPp_t^2 \,.\, Energy_t \,.\, AltEnergy_t \,.\, Agri_t \,.\, Indust_t \,.\, Serv_t) \quad (B1)$$

Noting that all variables were transformed to their natural logarithm to avoid any zero values.

Next, to transform equations (A1) and (B1) into working econometric models, the suitable regression model needed to be identified first. The approach outlined by Nkoro and Uko (2016) was used and is summarized in figure (6).

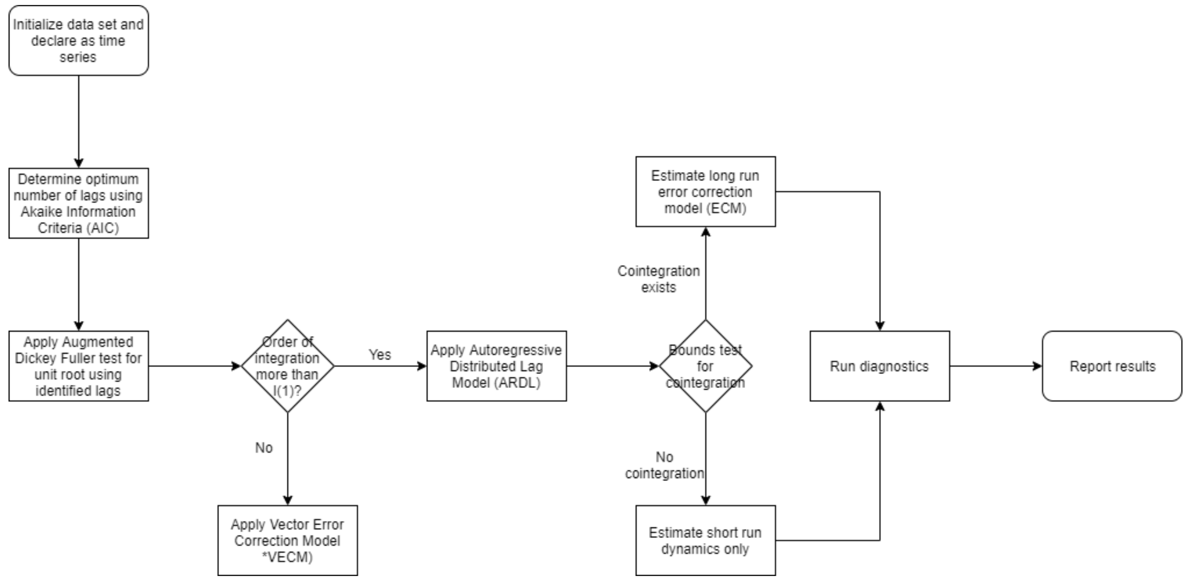


Figure 6: Approach to determince suitable regression model

As time series data is under study, it is important to test for staionarity. Applying OLS regression on non – stationary data can lead to spurious regression (Granger and Newbold, 1974). To do so, and to allow for possible correlations in error terms, the Augmented Dickey – Fuller (ADF) technique proposed by Dickey and Fuller (1981) is applied which identifies the order of integration for each variable series, i.e. the number of differences needed to transform the series into stationary. This is important because having variables with orders of integration higher than I(1), only the Autoregressive Distributed Lag (ARDL) model developed by Pesaran et al. (2001) can be applied.

Next step is to identify the existence of a long run relationship between the variables. Again this is done through the ARDL bounds test for cointegration, which is a special case in which the difference between a pair of non - stationary integrated series is stationary (Granger, 2004). In such test, the generated F – statistic value is compared to the critical values of I(0) and I(1) bounds. The model is said to have cointegration if the F – statistic value is higher than the I(1) critical values, meaning that an error correction model (ECM) can be estimated to account for long run equilibrium relationship among the time series variables. According to the determined optimum lag length for each variable, the ARDL model is specified as ARDL (p, q1, q2, q3, q4, q5, q6, q7), where p is the lag length for the dependent variable and q represent lag lengths for each explanatory variable. Equations (A2) and (B2) represent the specified models for regressions (A) and (B) respectively.

$$\Delta CO_{2_t} = \alpha_0 + \sum_{i=1}^{p} \beta_{1i} \Delta CO_{2_{t-i}} + \sum_{i=1}^{q1} \beta_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{q2} \beta_{3i} \Delta GDP_{t-i}^2 + \sum_{i=1}^{q3} \beta_{4i} \Delta Energy_{t-i} + \sum_{i=1}^{q4} \beta_{5i} \Delta AltEnergy_{t-i} + \sum_{i=1}^{q5} \beta_{6i} \Delta Agri_{t-i} + \sum_{i=1}^{q6} \beta_{7i} \Delta Indust_{t-i} + \sum_{i=1}^{q7} \beta_{8i} \Delta Serv_{t-i} + \lambda ECT_{t-1} + e_t \quad \text{(A2)}$$

And

$$\Delta SO_{2_t} = \alpha_0 + \sum_{i=1}^{p} \beta_{1i} \Delta CO_{2_{t-i}} + \sum_{i=1}^{q1} \beta_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{q2} \beta_{3i} \Delta GDP_{t-i}^2 + \sum_{i=1}^{q3} \beta_{4i} \Delta Energy_{t-i} + \sum_{i=1}^{q4} \beta_{5i} \Delta AltEnergy_{t-i} + \sum_{i=1}^{q5} \beta_{6i} \Delta Agri_{t-i} + \sum_{i=1}^{q6} \beta_{7i} \Delta Indust_{t-i} + \sum_{i=1}^{q7} \beta_{8i} \Delta Serv_{t-i} + \lambda ECT_{t-1} + e_t \quad \text{(B2)}$$

Where, the two equations contain both short run dynamics terms as well as error correction term (ECT) for the long run relationship.

After specifying and estimating the models, several diagnostic tests are performed including the Durbin-Watson test for serial correlation (1950), the Breusch-Godfrey test (Dimitrios and Stephen, 2011) for autocorrelation, White test (1980) and Breusch-Pagan test (1979) for homoscedasticity, in addition to the visual inspection of residuals to ensure that a pattern does not exist.

Empirical Results:

Having employed the Augmented Dickey-Fuller (ADF) test for stationarity. Table (4) summarizes the results of the ADF test for models (A) and (B). It can be interpreted that for model (A), all variables were found to be non – stationary at the level form. Moreover, all variables are integrated of order two I(2) at the 1% significance level, except for CO_2 emissions per capita which is integrated of order one I(1) at the 1% significance level.

As for model (B), it can be seen that all variables are integrated of first order I(1) at the 1% significance level except for SO_2 amount in air and energy use per capita which are integrated of second order I(2) at the 1% significance level.

Table 4: ADF test for stationarity results for models (A) and (B)

VARIABLES	ADF test statistic: model (A)	ADF test statistic: model (B)
Ln (C/SO_2 emissions per capita)	-1.020	-0.665
Ln (GDP per capita)	-1.381	-1.311
Ln (GDP per capita squared)	-1.122	-1.026
Ln (Energy use per capita)	-3.386**	-2.153
Ln (Alternative energy use per capita)	-0.987	-0.633
Ln (Agriculture sector value added to GDP)	-1.610	-1.489
Ln (Industrial sector value added to GDP	-1.272	-1.206
Ln (Services sector value added to GDP	-1.335	-1.296
	First difference	
∆Ln (C/SO_2 emissions per capita)	-3.990***	-2.781*
∆Ln (GDP per capita)	-2.614*	-3.893***
∆Ln (GDP per capita squared)	-2.548	-3.710***
∆Ln (Energy use per capita)	-2.202	-3.192**
∆Ln (Alternative energy use per capita)	-2.766*	-3.818***
∆Ln (Agriculture sector value added to GDP)	-2.969**	-3.893***
∆Ln (Industrial sector value added to GDP	-3.168**	-4.085***
∆Ln (Services sector value added to GDP	-2.729*	-3.849***
	Second difference	
∆∆Ln (C/SO_2 emissions per capita)	N/A	-4.437***
∆∆Ln (GDP per capita)	-5.353***	N/A
∆∆Ln (GDP per capita squared)	-5.157***	N/A
∆∆Ln (Energy use per capita)	-5.445***	-7.214***
∆∆Ln (Alternative energy use per capita)	-5.728***	N/A
∆∆Ln (Agriculture sector value added to GDP)	-5.570***	N/A
∆∆Ln (Industrial sector value added to GDP	-6.408***	N/A
∆∆Ln (Services sector value added to GDP	-5.335***	N/A
	***, ** and *** indicate 10%, 5% and 1% significance levels respectively. N/A: test not applied**	

As for the results of the ARDL bounds test for cointegration, Akaike Information Criterion (AIC) was used to identify the optimum lag for each variable while setting the maximum lag for model (A) to two lags, and for model (B) following the previous literature and to account for the limitation of small number of data points available. Table (5) reports the results of the bounds test for model (A) with optimum lag structure (1 0 0 0 0 1 0 1) and table (6) reports them for model (B) with identified lag structure (1 0 0 0 0 1 0 1). Comparing the values of F – statistic with the I(1) bounds value for each mode, it can be inferred that cointegration exists for both models, which was also confirmed by the less powerful Johansen test for cointegration. This simply means that there exists a long run relationship among the variables and an error correction model (ECM) can be estimated.

Table 5: Results of the bounds test for model (A) (Null Hypothesis: No levels relationship)

Significance %	I(0) Bound	I(1) Bound
10	2.03	3.12
5	2.32	3.50
2.5	2.60	3.84
1	2.96	4.26
F – statistic	5.481	

Table 6: Results of the bounds test for model (B) ((Null Hypothesis: No levels relationship))

Significance %	I(0) Bound	I(1) Bound
10	2.03	3.13
5	2.32	3.50
2.5	2.60	3.84
1	2.96	4.26
F – statistic	79.880	

Next, having determined that for both models and error correction model can be estimated. The ARDL model was run with the option *ec* set on *STATA* software to compute the short run coefficients as well as the error correction terms. Table (7) reports the results of the regression for model (A), while table (8) reports them for model (B) along with the statistical significance levels for each coefficient. As for the diagnostic tests performed, the results are reported in table (9) for both models. Figures (7) and (8) show the distribution of residuals plot for models (A) and (B) respectively. A detailed discussion of the meanings of the obtained results and their implications on policy is laid out in the following sections.

Table 7: Results of regression for model (A)

VARIABLES	(1) ADJ	(2) LR	(3) SR
lnGDP_perCap		1.090*	
		(0.620)	
lnGDPperCap2		-0.0839**	
		(0.0342)	
lnEnergyUsePerCap		0.551***	
		(0.179)	
lnAltEnergyUse		0.0136	
		(0.121)	
lnAgri		0.630***	
		(0.177)	
lnIndust		0.322***	
		(0.106)	
lnServ		-0.615**	
		(0.276)	
L.lnCO2	-0.775***		
	(0.154)		
D.lnAgri			-0.169
			(0.112)
D.lnServ			0.216*
			(0.112)
Constant			-10.76***
			(3.597)
Observations	42	42	42
R-squared	0.602	0.602	0.602

Table 8: Results of regression for model (B)

VARIABLES	(1) ADJ	(2) LR	(3) SR
lnGDP_perCap		-35.78	
		(18.31)	
lnGDPperCap2		3.686	
		(1.540)	
lnEnergyUsePerCap		5.065	
		(2.438)	
lnAltEnergyUse		1.794	
		(0.817)	
lnAgri		-8.737*	
		(2.413)	
lnIndust		-2.317	
		(1.528)	
lnServ		-8.305**	
		(1.386)	
L.lnSO2	-0.906**		
	(0.128)		
D.lnGDPperCap2			-0.0194
			(0.197)
D.lnEnergyUsePerCap			-3.791**
			(0.531)
D.lnAgri			3.592*
			(1.126)
D.lnIndust			-3.734
			(1.608)
Constant			453.3**
			(84.25)
Observations	15	15	15
R-squared	0.997	0.997	0.997

Table 9: Diagnostic statistics results for both models

	Model (A)		Model (B)	
Test	**Test statistic**	**Verdict**	**Test statistic**	**Verdict**
Durbin-Watson for serial autocorrelation	2.195	Inconclusive	3.131	Inconclusive
Breusch-Godfrey test for autocorrelation	0.532	No autocorrelation	0.0009	Autocorrelation exists
White test for homoscedasticity	0.4274	Homoskedastic	0.3782	Homoskedastic
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	0.4655	Homoskedastic	0.7326	Homoskedastic
Ramsey test for omitted variable bias	0.4449	No omitted variables	N/A	N/A

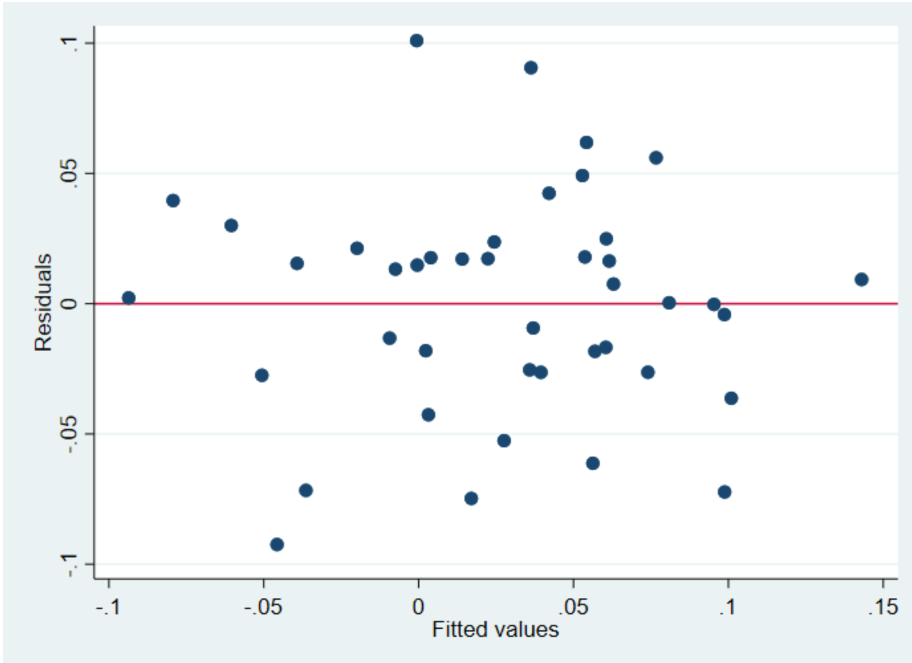


Figure 7: Residuals plot for model (A)

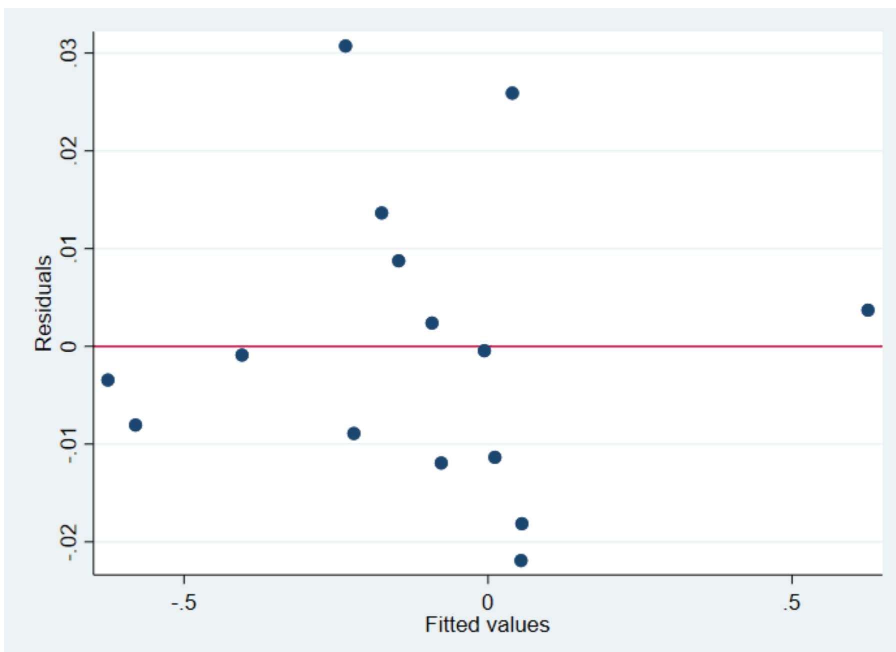


Figure 8: Residuals plot for model (B)

Discussion of Results:

Model (A)

Analyzing the regressions results for model (A), reported in table (7), it can be seen that on the long run, an inverted U – shaped relationship is present between the CO_2 emissions per capita and GDP per capita and its square. This is inferred from the positive coefficient of lnGDP_perCap and negative coefficient of lnGDPperCap2. Nevertheless, this result must be taken with skepticism as the two coefficients are significant at only 10% and 5% levels respectively. More significantly, however, a positive coefficient significant at 1% level was found for lnEnergyUsePerCap, lnAgri and lnIndust. This can be understood in the ceteris paribus sense that a 1% increase in energy use per capita, value added from agricultural sector to GDP and value added from industry to GDP will lead to a 0.5%, 0.6% and 0.3% increase in CO_2 emissions per capita respectively. The error correction term for the first lag of CO_2 emissions per capita was found to be significant at 1% level.

As for the short run dynamics, none of the coefficients were found to be statistically significant. Hence, there is no evidence for an inverted U – shaped relationship. From the above, the conclusion of this study is that there is no evidence for the validity of the EKC hypothesis for CO_2 in Egypt either on the long or short runs.

Model (B)

Applying the same analysis on the results of model (B), no statistically significant at 1% level relationships were found on the long or short run. Only the value added from service industry was found to have negative coefficient on the long run at 5% significance level, and energy use per capita on the short run. This result shows that there is no evidence for the validity of EKC hypothesis for SO_2 in Egypt on both the long and short runs. Nevertheless, this regression is applied on a fairly limited time frame (1999 to 2016) due to the limited availability of SO_2 readings in Egypt. This paper recommends re-applying the same study once more data points are available for this variable to confirm the obtained results.

Policy Recommendations:

Having examined the relationship between environmental degradation and economic development in Egypt using two different environmental indicators, the proposed EKC relationship was not confirmed to be true. This has important policy implications as it signifies that economic development alone is not enough to reduce levels of pollution. Governments in Egypt must actively employ programs aiming at reducing polluting emissions and improving the overall state of the environment.

In this regard, it is important to differentiate between pollutants as each has its own nature and can be treated differently. For example, SO_2 is highly localized and its concentrations in air can easily be reduced with programs like installing filters in factories or decommissioning older vehicles. This is apparent from the fast and sharp drop in its concentrations as seen in figure (2). On the other hand, CO_2 is more global and effects of local policies do not have as much impact without global cooperation. A direct policy implication would be the necessity of multinational programs under the different UN and other international bodies' frameworks.

Another important recommendation is the regarding the accurate and regular measurements and reporting of environmental quality indicators. This study, especially with model (B), is rendered less reliable due to the limited time period of measurements. Relevant authorities should take necessary steps to improve measurement as well as the frequency and quality of reporting.

As for the sectorial composition of GDP, the services sector is found to be negatively correlated with environmental degradation in both models, although only at 5% significance level. Hence, environmentally concerned businesses and government bodies are encouraged to pivot towards the services sector as it represents the least polluting sector of the economy.

Finally, analyzing the relationship between energy use and the environment. This study recommends taking steps to reduce energy consumption per capita through subsidy reforms, deploying of energy – efficient machinery and other policies. The empirical results show that investing in reducing overall energy consumption is more environmentally worthwhile than investing in renewable energy generation facilities, at least in the early phases of green energy adoption.

Conclusions:

This study analyzed the relationship between environmental degradation and economic development in Egypt through two separate ARDL regression models. The specified models accounted for other explanatory variables besides GDP per capita to improve reliability, namely: energy use per capita, alternative energy use per capita and values added from the agricultural, industrial and services sector in GDP. The results of regression did not confirm the presence of the EKC hypothesis for Egypt on both short on long runs. Moreover, multiple diagnostic tests were performed to ensure the validity and stability of the specified models. In addition, several policy implications were identified from the results and recommendations were proposed for the public and private sectors.

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